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1

FUN WITH PHYSICAL PARADOXES, PUZZLES, AND PROBLEMS

1.1 Introduction

A good physical paradox is (1) a surprise, (2) a puzzle, and (3) a lesson, rolled into one fun package. A paradox often involves a very convincing argument leading to a wrong conclusion that seems right, or to a right conclusion that seems wrong or surprising. The challenge to find the mistake—or explain the surprise—may be hard to resist. A joke heard back in the Cold War years claimed that the West could impede Soviet military R&D efforts by scattering leaflets containing puzzlers and brainteasers over the secret Siberian weapons research facilities. Times have changed, and these same brainteasers now are used in hiring interviews. As a Soviet propagandist would have said: either way, they are a capitalist tool.

Resolving a paradox is not only fun; it also trains intuition, logic, and critical thinking. One becomes a better lie detector by resolving paradoxes. A good paradox also teaches caution and humility by showing us how easy it is to go wrong even in relatively simple matters of elementary physics. It is liberating to know that some very smart people

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have made mistakes in seemingly simple matters of basic physics. Other fields—such as astronomy, biology, medicine, economics, climate, politics, and media—deal with more complicated objects than physics,[1] offering even more room for mistakes there. In addition, some ‘mistakes’ can be beneficial, at least temporarily.

My main reason in writing this book is to share the fun of imagining how things work. These paradoxes also teach the gist of some physics without the pain of mathematics.[2]

The puzzles in this book deal with physics—a subject that walks on two legs, one being mathematics, and the other, physical intuition. Unfortunately, in school the subject is often presented with a severe limp.

A musical analogy. If music were taught the way physics often is taught, we would learn the notes but not the melodies they produce. For too many students of physics, the subject is reduced to a collection of formulas that must be matched to a problem at hand. Not surprisingly, many intelligent students are turned off.

Intuition should come first. Exercise of physical intuition is one *practical* benefit of this book’s puzzles. All too many physics courses give short shrift to intuition, emphasizing instead a search for the formula that fits the situation. Examples in this book go in the opposite direction: I tried for a minimum of formulas and a maximum of intuition. The discussion of the spinning top is an example, where I give a formula-free explanation of why the spinning top stays

[1] This is not a statement on the relative difficulty of various sciences. I am simply referring to the fact that a physicist deals with much simpler objects (e.g., crystals) than a biologist (e.g., a cell).

[2] I refer to “pain" with tongue in cheek—mathematics is of course indispensable and beautiful to me, at least, since it’s my job.

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upright. It takes quite a few years of study in mathematics and physics to learn to write differential equations for the motion of a spinning top and to see how to deduce stability from these equations. And at the end of this long study few students end up with an intuitive understanding of why a spinning top stays up. The most powerful tool—our physical intuition—ends up unused.

1.2 Background

Much (but not all) of this book should be accessible to readers without formal background in physics. All physical concepts used are explained in the appendix. Mathematics in this book does not go beyond algebra, with a couple of exceptions where calculus is used. Even there, the reader who is willing to take a little math on trust should not be snagged by these references.[3]

Attraction to anything surprising is a basic instinct in most living creatures, or, at least, most mammals. By driving us to explore, the instinct helps us survive—with some exceptions, such as Darwin Prize winners or the heroes of Jackass. The same instinct that drove Einstein to his great discoveries also drives a curious child to see what's inside a mechanical clock. It even drives puppies and cubs to explore. In some people this instinct is so strong it can survive the educational system.

1.3 Sources

This book grew out of a collection of puzzles I started long ago on my father's advice, after I showed him one that

[3] I am referring here to the sling problem on page 93 where the rock reaches infinite speed after one second.

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occurred to me after a high school class on the capillary effect (page 128). Although I invented some of this book's puzzles,[4] *it is most likely that others thought of them or of something equivalent before I was born.* When I know the author or the origin of a puzzle, I make a reference.

Literature. Fortunately, much of the essence of basic physics can be understood, and enjoyed, without (m)any formulas, as some excellent popular books demonstrate. Among these are Walker's *The Flying Circus of Physics*, Epstein's *Thinking Physics*, Jargodzki and Potter's *Mad about Physics*, and Perelman's classic *Physics for Entertainment*. Unfortunately, Makovetsky's delightful book *Smotri v koren*' (a loose translation: "Seek the essence"), which sold over a million copies in the former Soviet Union, does not seem to have been translated into English. Minnaert's *The Nature of Light and Color in the Open Air*, dedicated to optical phenomena in nature, will never age and will give pleasure to any curious individual lucky enough to open it.

[4] For example, 2.1, 2.3, 2.4, 3.1, 3.2, 3.5, 3.6, 4.1, 4.2, 4.4–4.6, 5.3–5.8, 6.6, 6.7, 6.10–6.12, 8.2, 8.5, 8.6, 9.4, 11.1, 12.3, 13.2, 14.6, 14.8.